



US010001788B2

(12) **United States Patent**  
**McNeely et al.**

(10) **Patent No.:** **US 10,001,788 B2**  
(45) **Date of Patent:** **Jun. 19, 2018**

(54) **LOW PRESSURE PILOT OPERATED RELIEF VALVE**

(71) Applicant: **Emerson Vulcan Holding LLC**, St. Louis, MO (US)

(72) Inventors: **Michael McNeely**, Stafford, TX (US);  
**Michael Marcellus**, Stafford, TX (US);  
**Stephen Simpson**, Stafford, TX (US)

(73) Assignee: **Emerson Vulcan Holding LLC**, St. Louis, MO (US)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/346,813**

(22) Filed: **Nov. 9, 2016**

(65) **Prior Publication Data**

US 2017/0052549 A1 Feb. 23, 2017

**Related U.S. Application Data**

(63) Continuation of application No. 14/600,943, filed on Jan. 20, 2015, now Pat. No. 9,519,294.

(60) Provisional application No. 61/928,850, filed on Jan. 17, 2014.

(51) **Int. Cl.**  
**F16K 17/02** (2006.01)  
**G05D 16/16** (2006.01)  
**F16K 31/126** (2006.01)  
**F16K 1/06** (2006.01)  
**F16K 27/02** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **G05D 16/16** (2013.01); **F16K 1/06** (2013.01); **F16K 17/02** (2013.01); **F16K 27/02** (2013.01); **F16K 31/1266** (2013.01); **Y10T 137/7764** (2015.04)

(58) **Field of Classification Search**  
CPC ..... G05D 16/16; F16K 1/06; F16K 27/02; F16K 31/1266; F16K 17/02; F16K 27/0209; Y10T 137/7764  
USPC ..... 251/366; 137/488-489  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,090,381 A 8/1937 Zagorski  
2,316,649 A 4/1943 Jurs  
2,342,472 A 2/1944 Jurs et al.  
2,570,432 A 10/1951 Dillon  
2,576,516 A 11/1951 Jurs  
(Continued)

FOREIGN PATENT DOCUMENTS

JP 2005273710 A 10/2005  
WO 2013006707 A1 1/2013

OTHER PUBLICATIONS

Extended European Search Report; PCT/US2015012067; dated Sep. 26, 2017; 7 pages.

(Continued)

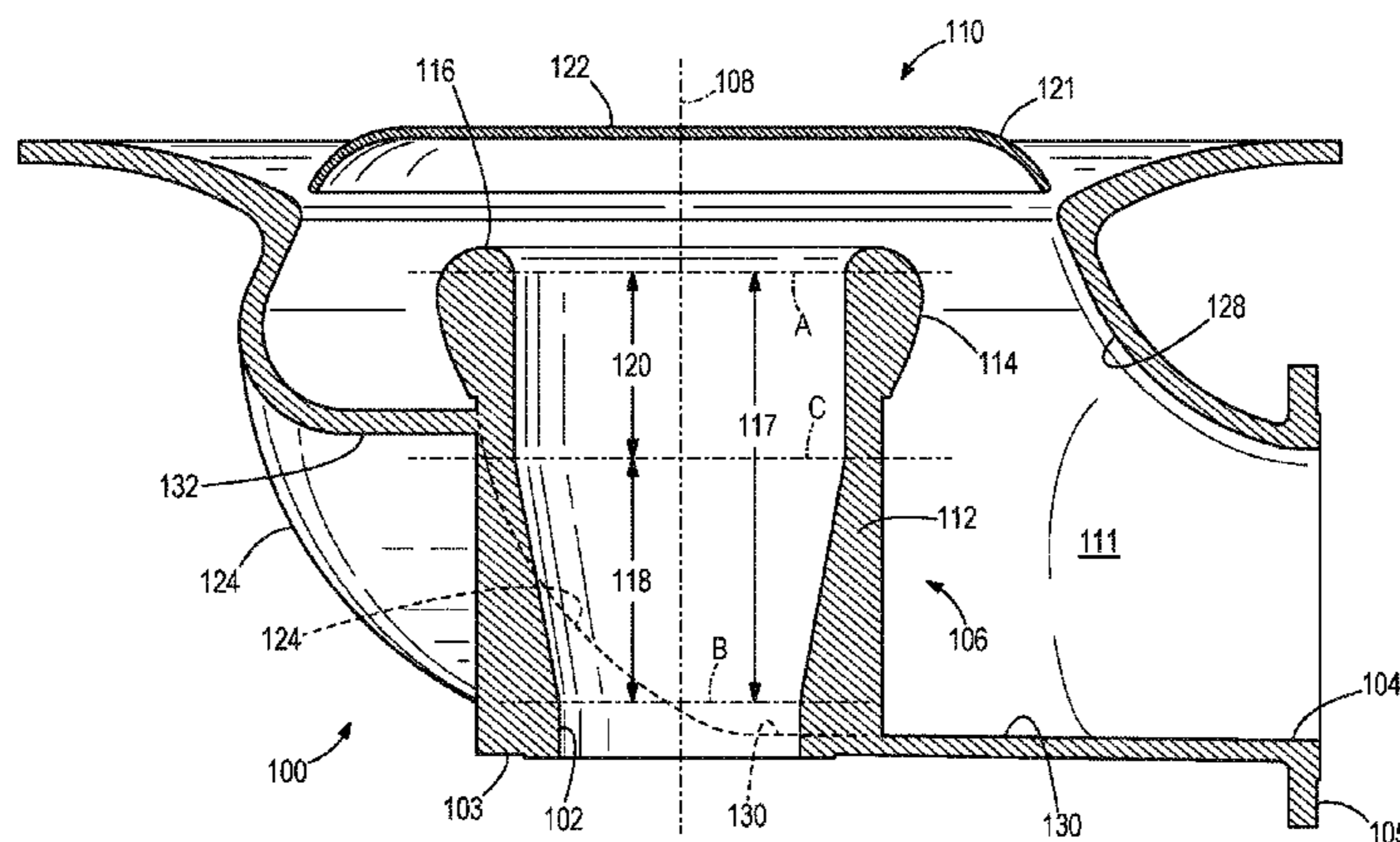
*Primary Examiner* — John Bastianelli

(74) *Attorney, Agent, or Firm* — Quarles & Brady LLP

(57) **ABSTRACT**

Embodiments of the invention provide a relief valve body arranged for connecting to a pressure vessel. The relief valve body includes an inlet configured to connect to a pressure vessel and an integrated nozzle downstream from the inlet and extending along an axis. The integrated nozzle includes a nozzle exterior surface, a nozzle bulb, and a valve seat and defines a nozzle expansion region. The relief valve body further includes a redirecting pallet, a valve interior surface having at least one ramped portion downstream from the integrated nozzle and redirecting pallet, and an outlet downstream from the at least one ramped portion.

**11 Claims, 4 Drawing Sheets**



(56)

**References Cited**

U.S. PATENT DOCUMENTS

2,785,861 A 3/1957 Kimm et al.  
 2,810,527 A 10/1957 Work  
 2,815,040 A 12/1957 Smith  
 3,294,111 A 12/1966 Abercrombie et al.  
 3,386,469 A 6/1968 Kelly  
 3,477,456 A 11/1969 Powell  
 3,592,224 A 7/1971 Bois  
 3,794,062 A 2/1974 AuWerter  
 3,881,505 A 5/1975 Dunkelis  
 4,091,837 A 5/1978 Edmunds et al.  
 4,129,142 A 12/1978 Solowy  
 4,172,466 A 10/1979 Pattarini et al.  
 4,312,375 A 1/1982 Leinemann  
 4,316,598 A 2/1982 Maggio  
 4,462,420 A 7/1984 Cullie  
 4,515,179 A 5/1985 Edmunds et al.

5,048,751 A 9/1991 DuBois  
 5,167,253 A 12/1992 Fournier et al.  
 5,511,581 A 4/1996 Ligh  
 5,555,910 A 9/1996 Powell et al.  
 5,909,747 A 6/1999 Schieber  
 5,913,330 A 6/1999 Jones et al.  
 5,924,673 A 7/1999 Welker  
 5,967,165 A 10/1999 Alberts  
 5,992,449 A 11/1999 Sprague  
 6,553,979 B2 4/2003 Albright  
 7,997,556 B2 8/2011 Migliorati  
 2008/0142091 A1 6/2008 Meinig et al.  
 2012/0205564 A1 8/2012 Klein et al.  
 2013/0213497 A1 8/2013 Helmsen et al.

OTHER PUBLICATIONS

International Search Report and Written Opinion for PCT/US2015/012067; dated May 5, 2015; 14 pages.

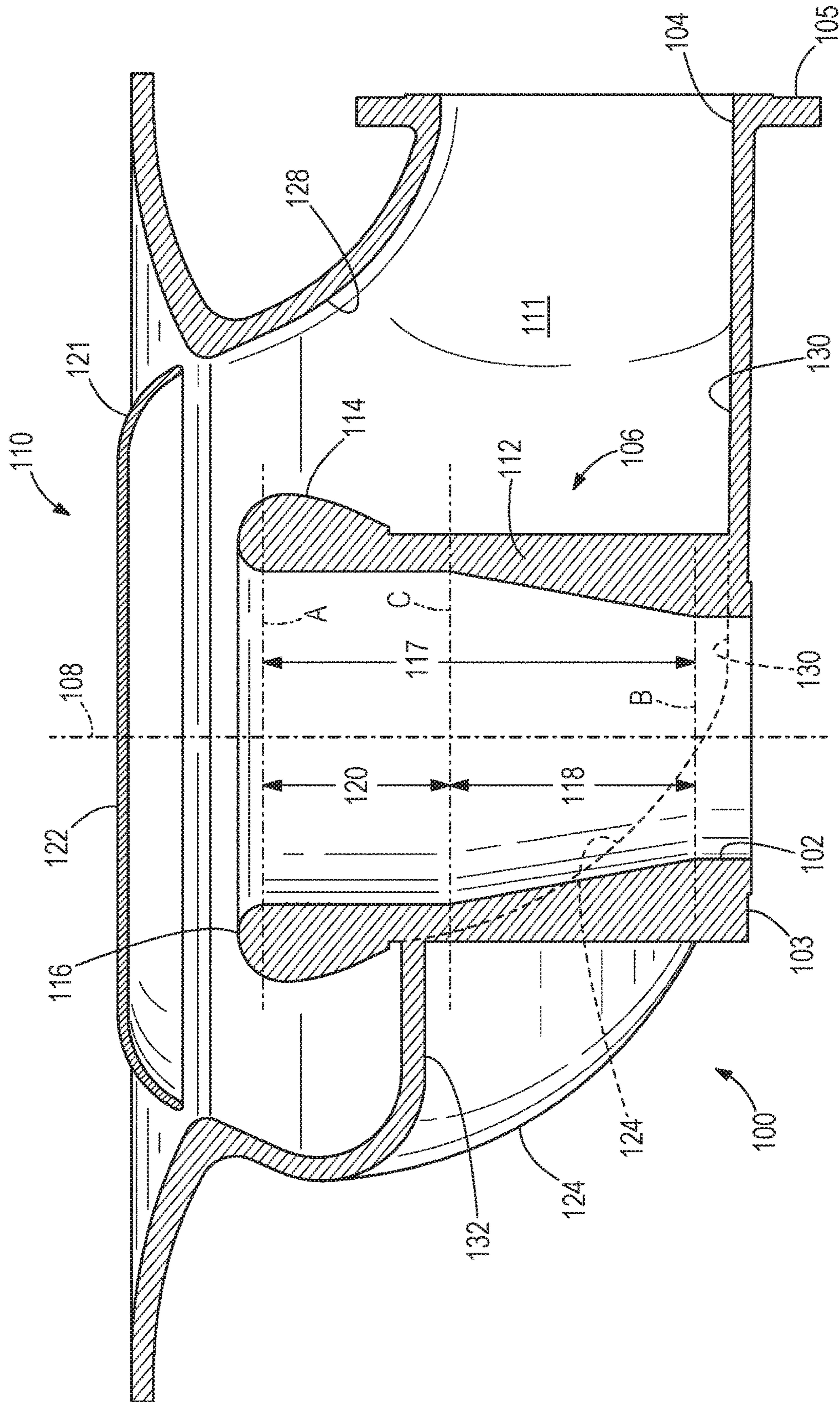


FIG. 1

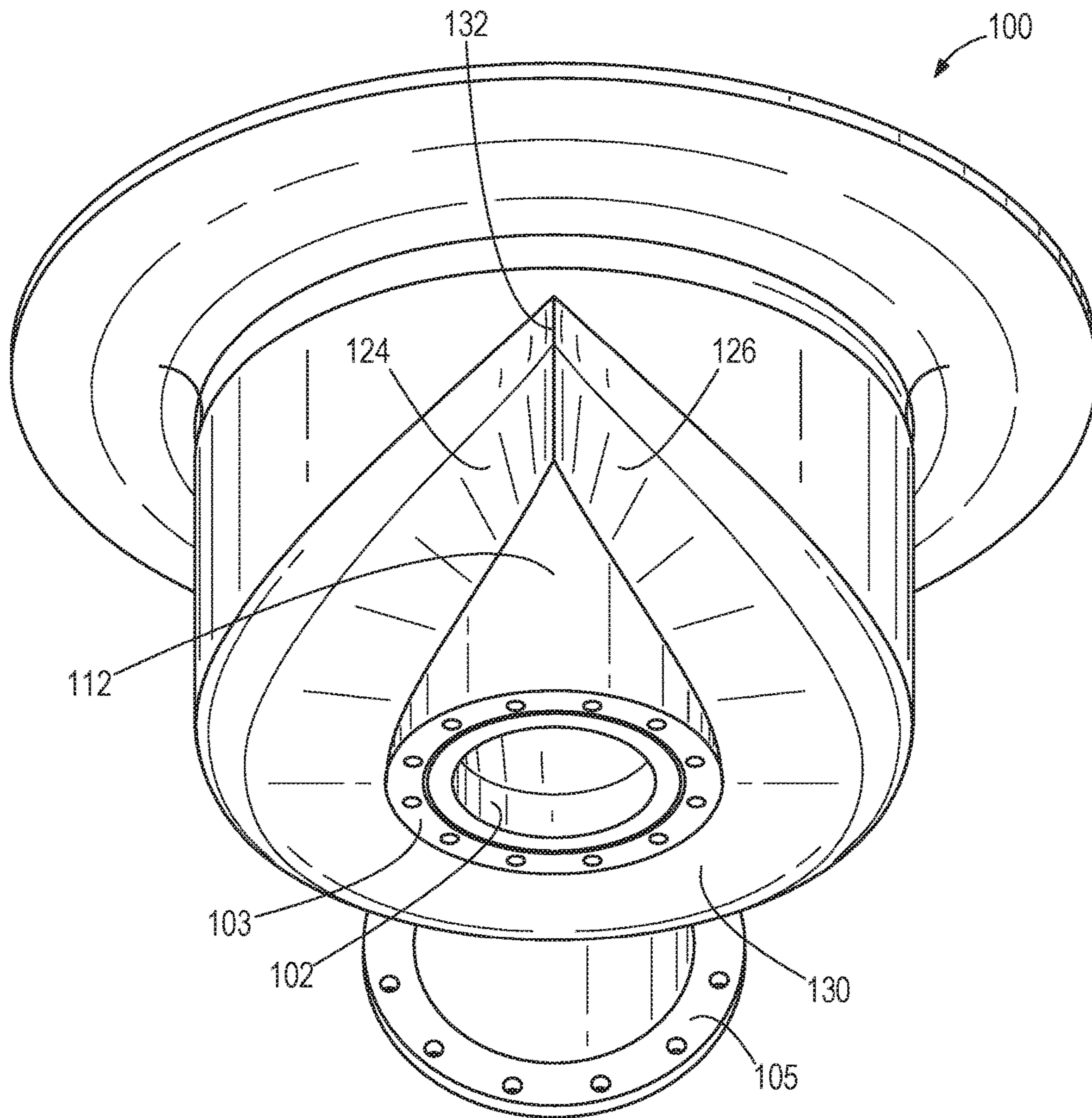
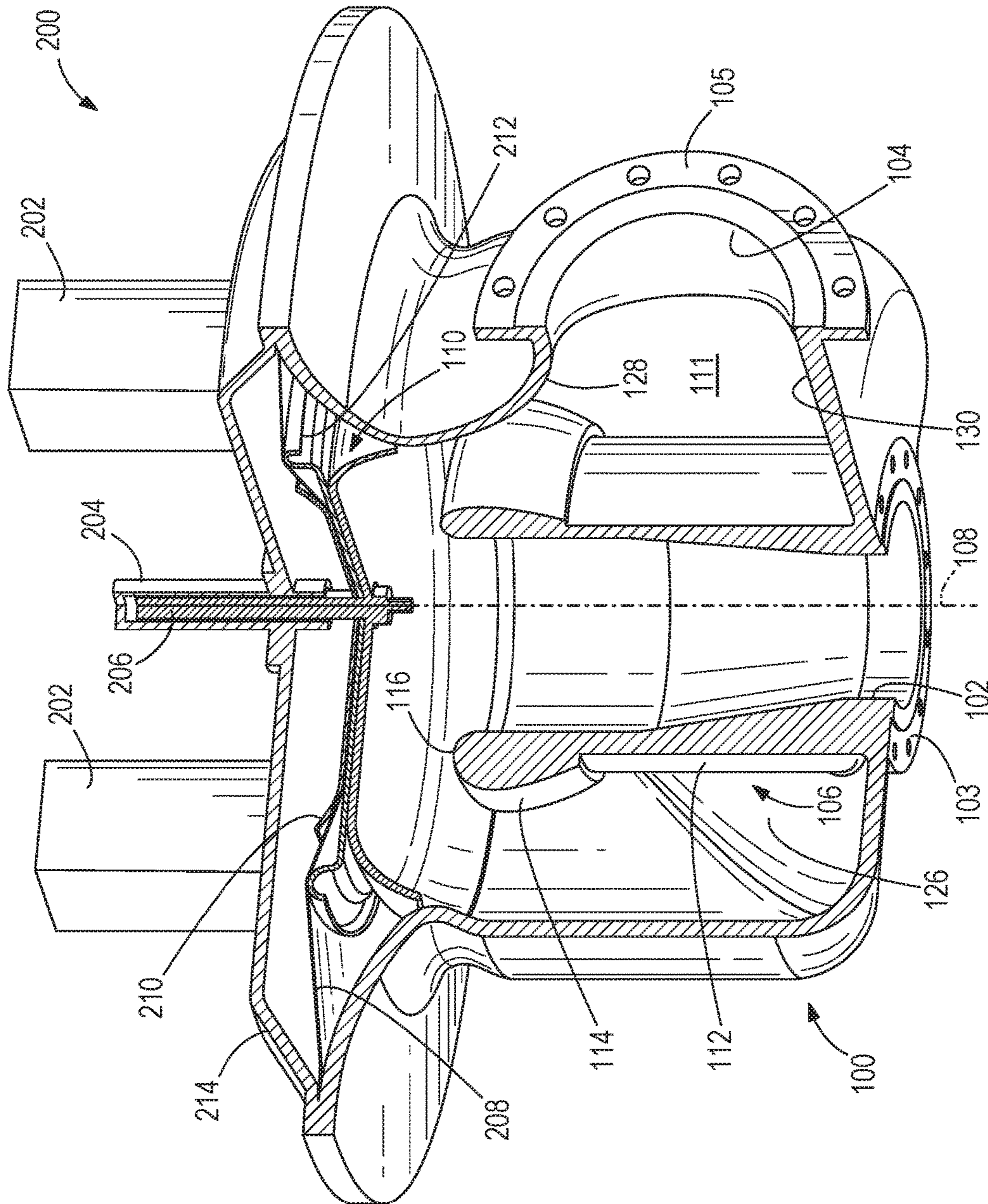


FIG. 2





**1****LOW PRESSURE PILOT OPERATED RELIEF VALVE****CROSS-REFERENCE TO RELATED APPLICATIONS**

This application is a continuation of co-pending U.S. patent application Ser. No. 14/600,943, filed on Jan. 30, 2015, and entitled “Low Pressure Pilot Operated Relief Valve”, which claims the benefit of United States Provisional Application No. 61/928,850 filed on Jan. 17, 2014, the entire disclosures of which are hereby incorporated herein by reference.

**BACKGROUND**

The present disclosure relates generally to relief valves for pressure vessels and, in particular, to pilot operated relief valves.

Current manufacturers commonly employ valve body designs intended to direct a fluid flow at a right angle with respect to an inlet without consideration to an expansion of the traversing fluid. Additionally, such designs typically do not provide means for controlling the expansion of the traversing fluid, and commonly rely solely on a cylindrical curtain area to allow the traversing fluid to pass into the valve body. Such valves deliver inferior flow rate efficiency through the valve body and, therefore, it would be desirable to have a valve body that provides a means to control the expansion of the traversing fluid through the valve body.

**BRIEF SUMMARY OF THE INVENTION**

The aforementioned shortcomings can be overcome by providing a relief valve body that includes features configured for increased efficiency of fluid flowing through the valve. Additionally, an interior shape of the inventive relief valve body allows for controlled expansion of the fluid and the management of the fluid energy in assisting in the change of direction of fluid flow. Such features may also provide advantages to applications employing any system, device, or structure wherein a fluid flow direction is changed in a controllable manner between an inlet and an outlet.

In one aspect, the invention provides a relief valve body arranged for connecting to a pressure vessel. The relief valve body includes an inlet configured to connect to a pressure vessel and an integrated nozzle downstream from the inlet and extending along an axis. The integrated nozzle includes a nozzle exterior surface, a nozzle bulb, and a valve seat and defines a nozzle expansion region. The relief valve body further includes a redirecting pallet, a valve interior surface having at least one ramped portion downstream from the integrated nozzle and redirecting pallet, and an outlet downstream from the at least one ramped portion.

In another aspect, the invention provides a relief valve body arranged between an inlet and an outlet. The relief valve body includes an expanding nozzle extending along an axis, a first ramp extending in an arcuate path from an apex to a first terminating point, and a second ramp extending in an arcuate path from the apex to a second terminal point. The first ramp and the second ramp define an expanding flow area for a fluid flow between the inlet and the outlet.

In another aspect, the invention provides a relief valve body arranged for connecting to a pressure vessel. The relief valve body includes an inlet for connecting to a pressure vessel and an integrated nozzle downstream from the inlet and extending along an axis. The integrated nozzle defines

**2**

a nozzle expansion region and includes a nozzle exterior surface, a nozzle bulb defining a substantially protrudent shape that protrudes away from the axis, and a valve seat. The relief valve body further includes a valve interior surface having a first ramped portion, a second ramped portion, a flat portion, and an arced portion. The first ramped portion expands a fluid flow area by ramping from a ramp apex around the integrated nozzle to the flat portion. The second ramped portion expands the fluid flow area by ramping from the ramp apex around the integrated nozzle to the flat portion on an opposite side of the integrated nozzle from the first ramped portion. The relief valve body further includes a redirecting pallet defining a curved portion and a flat portion that cooperate to direct a fluid flow towards the valve interior surface and an outlet downstream from the first ramped portion and the second ramped portion.

The foregoing and other aspects and advantages of the invention will appear from the following description. In the description, reference is made to the accompanying drawings which form a part hereof, and in which there is shown by way of illustration a preferred embodiment of the invention. Such embodiment does not necessarily represent the full scope of the invention however, and reference is made therefore to the claims and herein for interpreting the scope of the invention.

**BRIEF DESCRIPTION OF DRAWINGS**

The invention will be better understood and features, aspects and advantages other than those set forth above will become apparent when consideration is given to the following detailed description thereof. Such detailed description makes reference to the following drawings.

FIG. 1 is a cross-sectional side view of a relief valve body in accordance with the present invention.

FIG. 2 is a perspective, bottom view of the relief valve body of FIG. 1.

FIG. 3 is a perspective, top view of the relief valve body of FIG. 1 with a quarter cutout and the redirecting pallet removed.

FIG. 4 is a perspective, bottom view of an example relief valve with a quarter cutout.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

**DETAILED DESCRIPTION OF THE INVENTION**

Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of “including,” “comprising,” or “having” and variations thereof herein is meant to encom-

pass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms “mounted,” “connected,” “supported,” and “coupled” and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, “connected” and “coupled” are not restricted to physical or mechanical connections or couplings.

The following discussion is presented to enable a person skilled in the art to make and use embodiments of the invention. Various modifications to the illustrated embodiments will be readily apparent to those skilled in the art, and the generic principles herein can be applied to other embodiments and applications without departing from embodiments of the invention. Thus, embodiments of the invention are not intended to be limited to embodiments shown, but are to be accorded the widest scope consistent with the principles and features disclosed herein. The following detailed description is to be read with reference to the figures, in which like elements in different figures have like reference numerals. The figures, which are not necessarily to scale, depict selected embodiments and are not intended to limit the scope of embodiments of the invention. Skilled artisans will recognize the examples provided herein have many useful alternatives and fall within the scope of embodiments of the invention.

The present invention introduces a relief valve body **100** designed for use in any applications employing systems or components designed for maintaining fluid flows, such as, for example, systems, vessels or tankers used for processing, transporting or storing liquefied natural gas (LNG). Features of the relief valve body **100** in accordance with the present invention will be readily apparent and are generally indicated in FIGS. 1-4.

As shown in FIG. 1, the relief valve body **100** is configured to controllably divert a fluid flow between an inlet **102** and an outlet **104**. The inlet **102** is arranged at an angle of approximately 90 degrees with respect to the outlet **104**. In other embodiments, the inlet **102** may be arranged at a different angle with respect to the outlet **104**, as desired. The inlet **102** and the outlet **104** of the relief valve body **100** can be designed with capabilities and/or components for coupling to a fluid-bearing vessel, device, or system. In the illustrated embodiment, the inlet **102** includes an inlet mounting feature **103** in the form of a flange and the outlet **104** includes an outlet mounting feature **105** in the form of a flange. In other embodiments, the inlet mounting feature **103** and/or the outlet mounting feature **105** may be in the form of a threaded pipe fitting or be arranged differently, as desired.

The relief valve body **100** includes an integrated nozzle **106** downstream from the inlet **102** and extending along an axis **108**, a redirecting pallet **110**, and a valve interior surface **111** arranged downstream from the integrated nozzle **106** and the redirecting pallet **110**. The integrated nozzle **106** includes a nozzle exterior surface **112**, a nozzle bulb **114**, and a valve seat **116** configured to couple to a valve element (not shown) of a pressure relief valve system. The integrated nozzle **106** defines a nozzle expansion region **117** generally bounded between plane A and plane B and indicated as element **117**. The nozzle expansion region can be shaped and dimensioned to enable a controlled expansion of the fluid flow from the inlet **102** and through the integrated nozzle **106** generally along the axis **108**. In the illustrated embodiment, the nozzle expansion region **117** includes a tapered portion generally bounded between plane B and plane C and indicated as element **118** that defines a substantially frusto-

conical, or sloped shape and a nozzle exit portion **120**, downstream from the tapered portion **118**, generally bounded between plane A and plane C and indicated by element **120**.

The expansion of the fluid flow traversing the nozzle expansion region **117** of the integrated nozzle **106** may be controlled by an expansion ratio  $R_{exp}$  defined by the tapered portion **118**. In the illustrated embodiment, the expansion ratio  $R_{exp}$  of the tapered portion **118** is approximately 1.8. In other embodiments, the tapered portion **118** can define a different expansion ratio  $R_{exp}$ , as desired. For example, the expansion ratio  $R_{exp}$  may be between about 1.7 and 1.9, or in other embodiments, the expansion ratio  $R_{exp}$  may be between about 1.5 and 2.1. The shape of the integrated nozzle **106** allows for better control of expansion and a standing shock wave of a fluid. As such, the relief valve body **100** may be suitable for high pressure flow conditions.

The nozzle exterior surface **112** defines a generally cylindrical shape and is configured to be downstream from the nozzle bulb **114**. The nozzle bulb **114** defines a substantially arced, or protrudent shape that is configured to control a standing shock wave of the fluid flow as the fluid flow is being directed towards the valve interior surface **111**. The protrudent shape of the nozzle bulb **114** protrudes away from the axis **108**.

With continued reference to FIG. 1, the redirecting pallet **110** is configured to receive the fluid flow generally directed along the axis **108** from the inlet **102**, and divert the fluid flow in directions generally away from the axis **108** and towards the valve interior surface **111**. The redirecting pallet **110** can be designed to be substantially circular, although other shapes are possible. The redirecting pallet **110** defines a curved portion **121** and a flat portion **122** that cooperate to direct the fluid flow and develop a more laminar flow profile.

The shape of the redirecting pallet **110**, the nozzle bulb **114**, and the nozzle expansion region **117** are designed to cooperate and allow for control of the fluid flow as it flows through and away from the integrated nozzle **106**. For example, for higher pressure applications, the nozzle bulb **114** of the integrated nozzle **106** may be shaped to be more bulbous, or protrude further from the axis **108** than shown in FIG. 1, which would allow for a standing shock of the fluid flow to occur prior to entering the valve interior surface **111**. In contrast, for lower pressure applications, the nozzle bulb **114** of the integrated nozzle **106** may be shaped to be less bulbous, or protrude less from the axis **108** than shown in FIG. 1, which may allow for a more free fluid expansion into the valve interior surface **111**.

With reference to FIGS. 1-3, the valve interior surface **111** includes a first ramped portion **124**, a second ramped portion **126**, an arced portion **128**, and a flat portion **130**. The first ramped portion **124** begins at a ramp apex **132** and expands a fluid flow area for the fluid flow traveling along the first ramped portion **124** by ramping towards the outlet **104** and around the integrated nozzle **106**. The fluid flow area continues expanding until the first ramped portion **124** engages the flat portion **130**, as shown in FIG. 1 by the dashed lines illustrating the first ramped portion **124** and the flat portion **130**. The second ramped portion **126** begins at the ramp apex **132** and expands a fluid flow area for the fluid flow traveling along the second ramped portion **126** by ramping towards the outlet **104** and around the integrated nozzle **106**, in an opposite direction from the first ramped portion **124**. The fluid flow area continues expanding until the second ramped portion **126** engages the flat portion **130**. In the illustrated embodiment, the first ramped portion **124** and the second ramped portion **126** engage the flat portion **130** in a plane



## 5

closer to the outlet **104** than the axis **108**. In other embodiments, the first ramped portion **124** and the second ramped portion **126** may engage the flat portion **130** in a plane substantially further away, substantially closer to the outlet **104** than the axis **108**, or in a plane intersecting the axis **108**.

The arced portion **128** defines a gradually decreasing flow area for the fluid flow traveling towards the outlet **104** of the valve body **100**. The gradual decrease in fluid flow area provides a reduced pressure drop between the inlet **102** and the outlet **104** of the valve body **100**.

The expanded flow area provided by the first ramped portion **124** and the second ramped portion **126** provide a reduction in a velocity of the fluid flow traversing from the inlet **102** to the outlet **104** of the relief valve body **100**. This reduction in flow velocity aids in reducing a pressure drop between the inlet **102** and the **104**. Additionally, the reduced velocity of the fluid flow reduces the Reynolds number of the fluid flow and, therefore, reduces the chance of fluid separation, or turbulence, occurring downstream from the integrated nozzle **106**. Thus, the first ramped portion **124**, the second ramped portion **126**, the arced portion **128**, and the flat surface **130** enable a superior flow rate efficiency and retain a total pressure of the fluid flow by minimizing a pressure drop between the inlet **102** and the outlet **104** of the valve body **100**.

FIG. 4 illustrates a use for the relief valve body **100** described above. The relief valve body **100** may be integrated into a pilot operated relief valve **200**, which as known in the art, is used to provide gradual, proportional or pre-set pressure relief. The pilot operated relief valve **200** shown in FIG. 4 includes pilot valves **202**, a guide **204**, a guide pin **206**, and a diaphragm **208** adjacent to the redirecting pallet **110**. An upper blousing plate **210** and a lower blousing plate **212** are located adjacent to the diaphragm **208**. The pilot valves **202** are mounted on a cover **214** that is coupled to the valve body **100** and encloses the valve interior surface **111** and the diaphragm **208**.

Although not shown, the pilot operated relief valve **200** also includes a valve element removably coupled to the valve seat **116** of the integrated nozzle **106**. The valve element is typically formed from a flexible material and can be attached to a bottom surface of the redirecting pallet **110**. The valve element may include a valve element cover that can be formed from a polytetrafluoroethylene (PTFE) material, which lays over the valve element, serving as a protective layer.

Operation of the pilot operated relief valve **200** including the relief valve body **100** will be described with reference to FIG. 4. The valve element (not shown for clarity in describing the features of the relief valve body **100**) is typically biased towards a first position where fluid flow is prevented from the inlet **102** to the outlet **104** of the relief valve body **100**. Once a predetermined pressure is detected by the pilot valves **202**, the valve element is allowed to move from the first position to a second position where fluid flow is allowed between the inlet **102** and the outlet **104** of the relief valve body **100**. The fluid flow traveling from the inlet **102** to the outlet **104** is first expanded in the nozzle expansion region **117** downstream from the inlet **102**. The fluid flow then exits the integrated nozzle **106** through the nozzle exit region **120** and is directed towards the valve interior surface **111** by the redirecting pallet **110**. The first ramped portion **124** and the second ramped portion **126** then expand the fluid flow and direct the fluid flow towards the outlet **104** in an efficient manner.

The design of a relief valve body **100**, in accordance with the present invention, is focused on delivering superior flow

## 6

rate efficiency through the valve interior surface **111** of the valve body **100**, for example, in the case of subsonic fluid flow. The expansion characteristics of the fluid flow are tightly controlled through geometrical configurations of the integrated nozzle **106** features, the redirecting pallet **110** shape, and the design of the portions **124**, **126**, **128**, and **130** of the interior valve surface **111**. The controlled expansion of a gas, for example, minimizes losses and retains a total pressure as much as possible until the outlet **104** of the valve body **100**.

It will be appreciated by those skilled in the art that while the invention has been described above in connection with particular embodiments and examples, the invention is not necessarily so limited, and that numerous other embodiments, examples, uses, modifications and departures from the embodiments, examples and uses are intended to be encompassed by the claims attached hereto. The entire disclosure of each patent and publication cited herein is incorporated by reference, as if each such patent or publication were individually incorporated by reference herein.

We claim:

1. A relief valve body arranged for connecting to a pressure vessel, the relief valve body comprising:
  - an inlet configured to connect to a pressure vessel;
  - an integrated nozzle downstream from the inlet and extending along an axis, the integrated nozzle including a nozzle exterior surface, a nozzle bulb, and a valve seat and defining a nozzle expansion region;
  - a redirecting pallet;
  - a valve interior surface including at least one ramped portion downstream from the integrated nozzle and redirecting pallet;
  - an outlet downstream from the at least one ramped portion wherein the redirecting pallet defines a curved portion and a flat portion that cooperate to direct a fluid flow towards the valve interior surface; and
  - wherein the valve interior surface further includes an arced portion and a flat portion both connected to the outlet.
2. The relief valve body of claim 1, wherein the nozzle expansion region defines an expansion ratio  $R_{exp}$  of approximately 1.8.
3. The relief valve body of claim 1, wherein the nozzle expansion region defines an expansion ratio  $R_{exp}$  of between about 1.5 and about 2.1.
4. The relief valve body of claim 1, wherein the nozzle expansion region defines a substantially frusto-conical shape.
5. The relief valve body of claim 1, wherein the nozzle bulb defines a substantially protrudent shape that protrudes away from the axis.
6. The relief valve body of claim 1, wherein at least one ramped portion includes a first ramped portion and a second ramped portion.
7. The relief valve body of claim 6, wherein the first ramped portion begins at a ramp apex and expands a fluid flow area by ramping towards the outlet and around the integrated nozzle, and the second ramped portion begins at the ramp apex and expands the fluid flow area by ramping towards the outlet and around the integrated nozzle in an opposite direction from the first ramped portion.
8. The relief valve body of claim 7, wherein the first ramped portion and the second ramped portion engage the flat portion in a plane between the outlet and the axis.
9. The relief valve body of claim 7, wherein the first ramped portion and the second ramped portion engage the flat portion in a plane intersecting the axis.

10. The relief valve body of claim 7, wherein the first ramped portion and the second ramped portion engage the flat portion in a plane substantially further away from the outlet than the axis.

11. The relief valve body of claim 7, wherein the arced portion defines a decreasing flow area for a fluid flow traveling towards the outlet.

\* \* \* \* \*